Efficient SARS-CoV2 contact tracing and more using BLE

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Abstract

The COVID-19 pandemic has changed our lifestyle. Once someone is confirmed to be infected, it becomes necessary to track down the source so as to reduce further spread[3]. This paper proposes a software system which uses Bluetooth Low Engergy keeping in mind privacy while providing solutions for contact tracing, alerts and much more.

1. Introduction

1.1. The problem

As the number of cases grow exponentially, every country is finding it difficult to manage the large volume of patients. They are low on ventilators and are having to choose among patients who they think will be able survive the night. The only efficient way known to stop the spread is social distancing and locking down hotspots. This has slowed down the growth in many countries (including India [10]).

Although this has slowed it down, we still have increasing number of cases everyday. It is very important to track their source so as to declare a new hotspot for quarantining or stopping the spread. This is where contact tracing comes in.

1.2. Contact tracing

The COVID-19 virus entered India from outside [1](like every other country except China, because that's where it started). The most important thing in such a situation is to keep track of how it is spreading. The total count provides some information but we also need things like location, approximate time of contact, other contacts, etc.

1.3. Results

Once we have this unified system setup, we can expect things to start returning back to normal, at least for most of us. Here's how. Once we have this system in place, we will have information about people with high risk we will be able to go outside more safely, knowing that we will be alerted if some infected person (or one who has been in proximity of a positive person) is nearby.

Imagine, for example, if Starbucks' 30,000 global locations required patrons to tap their phone on a reader before entering the store, confirming they have contact tracing enabled, and are unlikely to have been in close quarters with a COVID-19 patient in the past two weeks. People will be able to go there and enjoy coffee again! [5]

Imagine if Uber made its app run the same check automatically on your device, so that before sending a car it confirmed you are low-risk for being contagious — and extended you the same peace of mind about the driver who picks you up. [5]

Almost everything can open up normally, when everybody is sure that they won't come in contact of a high risk person. People who do come close can self quarantine themselves! Earlier, this wouldn't have been detected until that person developed symptoms and tested positive about two weeks later.

This solution is really necessary to bring thing back to normal as fast as possible. Currently, no method is known which gives as high a reward given by this in such a simple way.

2. Literature Review

2.1. Introduction

The COVID-19 virus can attack the whole body, not just the lungs [8]. It affects those who are already facing medical issues mostly. Stopping this pandemic of paramount importance and there are various measures being taken in order to achieve the same.

Many countries are adopting contact tracing to find out the source of the infection. It's purpose is to identify contacts as early as possible for preventing spread of further transmission. Unfortunately, this is currently being handled in a very inefficient way. For e.g., a country like New Zealand which is virtually free of the virus now [9], used to do this manually by calling the infected, recalling whom

they met, maintaining sheets, etc [6].

Here is a flowchart depicting how a new COVID-19 case is managed in India

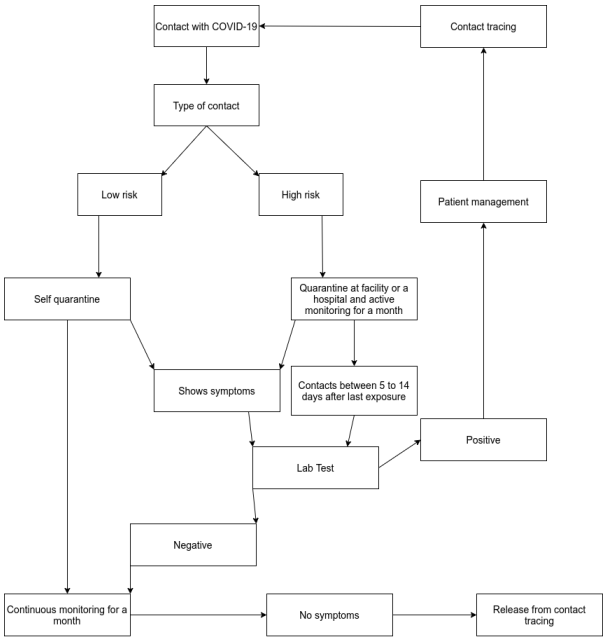

Figure 1: How India is managing contact tracing [11]

2.2. Digitalization

We live in an era where almost everything is digital. Why not make the process of contact tracing less tedious and more efficient by shifting it to the technological domain?

Some work has already started in this domain. Many countries like Singapore, Israel, China, Hong Kong, Iceland, India, Russia, Poland, (...and many more) have released their own contact tracing applications [5]. This has surely helped them in controlling the cases, but what we really need is something at the global level.

2.3. A unified solution

Google and Apple are working together on a unified solution to this which enforces privacy and uses bluetooth. They are planning to release an API for this too [4]. They are aiming at system level integration in the two most popular mobile platforms: Android and iOS. [2]

They have already released a developer version for this and system level integration is expected by mid-may. Their solution will be available in respective app stores and aims to fix a lot of problems and make the process of contact tracing much easier.

My idea builds on the same principles. I also explore some areas which haven't been explored yet.

3. System Architecture

3.1. Overview

Almost everybody has a mobile phone nowadays. Almost every mobile phone has bluetooth. This system uses Bluetooth broadcasts[13] to get a network of other devices present nearby. Each device is associated with a person who is given a probability of having the virus. 0.0 means no virus whereas 1.0 means the person is infected with it. Everything in between indicates the chance of that person having the virus.

The system keeps track of the people who have been near the user, for how long and how far the devices were. We can use the bluetooth signal strength to determine how far apart the people are[7].

If the probability(score) crosses a certain threshold, it is dangerous for them to be outside and they should contact a doctor immediately and get quarantined in a facility or hospital. The score is dynamic and can keep updating as often as one takes in a breath.

When a person tests positive for COVID-19, all the users who came in contact with the patient earlier can be alerted.

3.2. Description

This solution will be effective only if it is used at a large scale [5]. If only some people end up using it, none of the promised benefits would be possible. It has to be used by everybody, atleast within a country to be effective. If we are planning to open international travel again, this scope would have to expand to all the countries in the world instead of just a few.

Once the app is installed, it will broadcast the users' score to everybody in range (which is about 400m for BLE). We can use the signal strength to limit the range to the required distance.[7]

Each device acts as a peer in a connected network, just like the BitTorrent protocol [14].

3.3. The servers

My system does not exactly follow a server-client architecture but it also has a peer based architecture. There are some peers which have a special purpose and are not associated with a person. I will be referring to these kind of peers as L3(level 3) Servers.

The information of a new confirmed case needs to spread fast and the most important areas are the ones in close proximity to the infected person. To take care of this issue, I suggest a recursive DNS server like setup for these servers.

Some background on name servers [16]

- There are 13 logical root servers present all over the world which have information about the TLDs (top level domains).

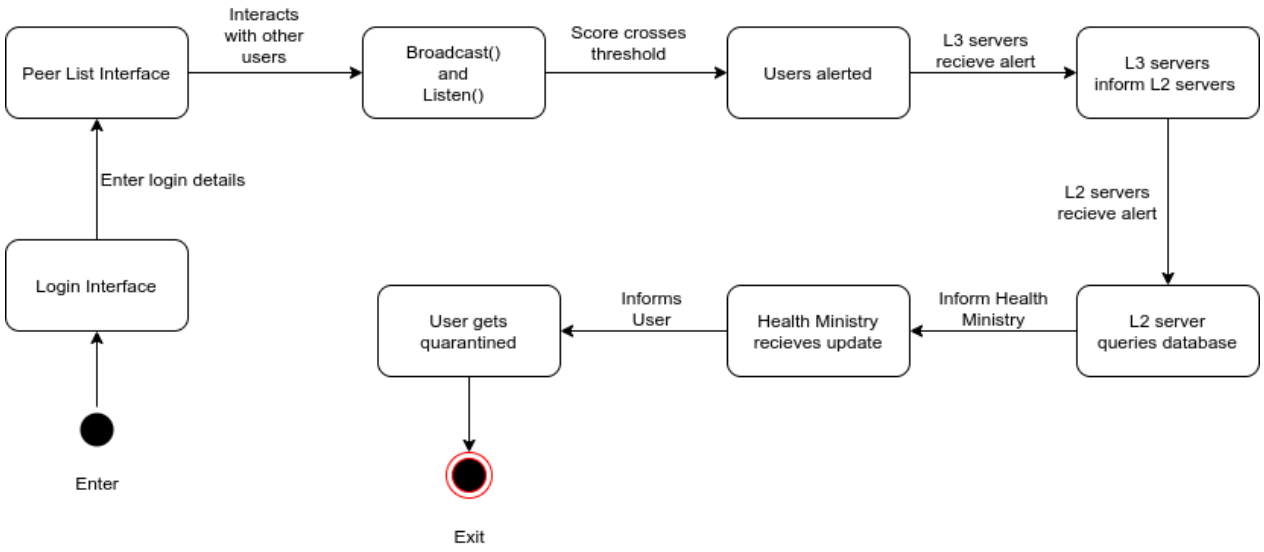

Figure 2: State diagram for a user who got infected

- Whenever someone queries for something, it goes to the closest nameserver. If it can find the entry, it returns it. Otherwise, it tries to find the next closest nameserver. This goes on till it reaches the root server.

Here is how I propose the server setup to be

- Each locality or district has a special device which acts just like any other peer but, it's score is the average of people around it. This can act as an indicator of the level of spread in that locality, how dangerous it is to visit that area. This is the L3 server.
- The L3 servers have no idea about the nation's identity system, it only keeps a list of mac addresses and their score. This enforces privacy.
- The L3 servers send their data to and receive their data from L2 servers.
- The L2 servers have information about the nation's identity system and has a mapping of bluetooth mac addresses and the person. It also receives information from the nation's Health Committee about new confirmed cases. It then sends this information to all the L3 servers.

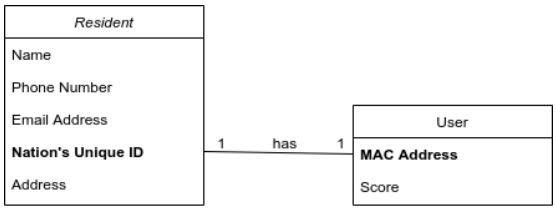

Figure 3: Data being stored at L2 (encrypted)

- These L2 servers may be distributed state-wise or even country wise depending on the size
- There can be a few L1 servers (just like root name servers) which have total number of cases across a continent or a group of countries. They don't store nation's identity system, etc. Just the count of every L2 server they manage.
- All servers at every level can expose an API which can give statistics about the growth of cases, the active count and it's locality. The exact specifications will vary across the different levels (L1,2,3) but this would be the minimum available at every level. Each server can also return the list of lower level servers they manage and how to access them.

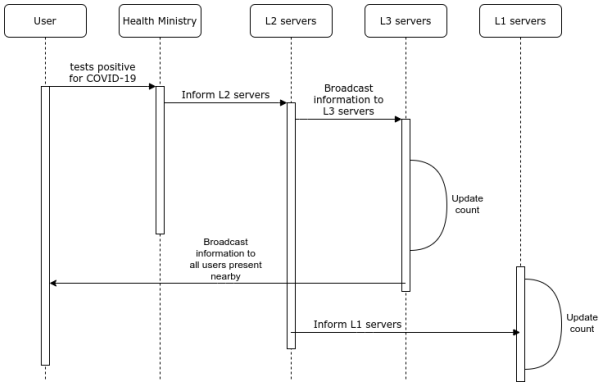

Figure 4: Sequence diagram for server interaction

3.4. The client

You must have turned on bluetooth for using wireless earphones or headphones. It starts listing all available devices. This happens because the earphones are broadcasting their device name, mac address, etc

I propose to use the same broadcasting functionality for communication between other clients and the L3 servers. Each device broadcasts it's score to the others. The application keeps track of other devices, the distance between them and the duration if two devices stay close for a long time.

Each such interaction is stored in the device and can later be used for contact tracing when any user tests positive for the virus. [See figure]

Score update delivery The score updates will be delivered via the same broadcast functionality through the L3 servers to other peers. The L3 servers get information about a new confirmed case from L2 servers which in turn get it from the Health Ministry of that country over the internet. So, there is no need of high speed internet for the users while it remains possible to communicate between servers over the internet.

3.5. User Story

The user installs the application and then logs into it using the nation's identity system (e.g. for India, it would be Aadhar card). Once they have logged in, the server has information about the user and the device's bluetooth interface's mac address. The score initialization is discussed here.

While logging in, the user will provide a password which will be used for encryption of any personal data which gets stored on the L2 servers. The password itself will not be stored, it's hash will be stored on the server. Along with that, the user will also provide their National Identification Number (e.g. for India, Aadhar number).

After this, the application pretty much runs in the background without much user interaction.

Now, whenever the user goes outside, the score will update internally. When the application detects someone with high risk, the user is alerted not to go there. This works with localities too since the L3 servers also act as regular peers while storing the average for that location.

When the user tests positive, every device in it's history is alerted and their score is updated. We can keep track of contacts this way and bring people for checkups if the risk of someone being infected becomes too high.

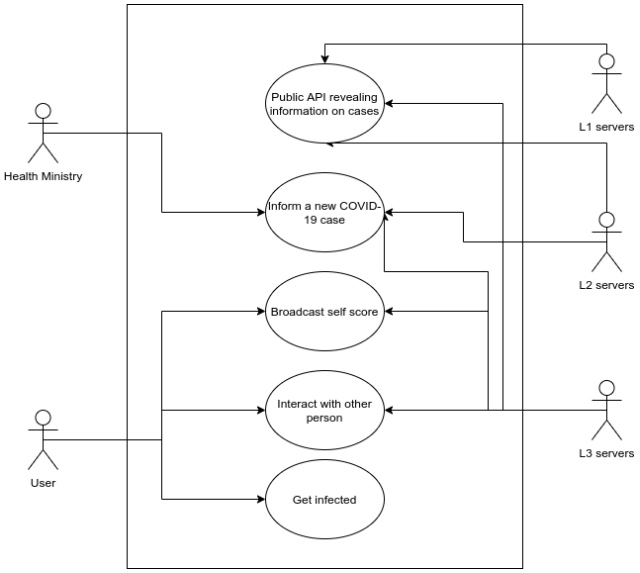

Figure 6: Use case diagram

3.6. The probability system

Score initialization The initial probability is a little tricky. If we already know that the person is COVID-19 positive, it is easy to initialize (=1.0) but otherwise, we don't know about them. The safest option can't be keeping it null until something is known about the users since it defeats the purpose.

We can't initialize with 0.0 since it might not true that the person is free of the virus and no harm at all. The safest way to initialize it would be a scaled average of the count of cases in that locality (at L3 server level).

Score updation This score gets updated whenever one or more of the following events occur:

- The user tests positive for COVID-19 after a medical test
- A person (someone in the user's contact list) tests positive for COVID-19 after a medical test
- The user gets into close proximity with another user. Their individual scores, duration of close contact and the distance between them will be used.
- It decays by some amount over time if no contact has been made and it's below some threshold.
- It reduces (but not to 0.0) when a person tests negative for the virus.

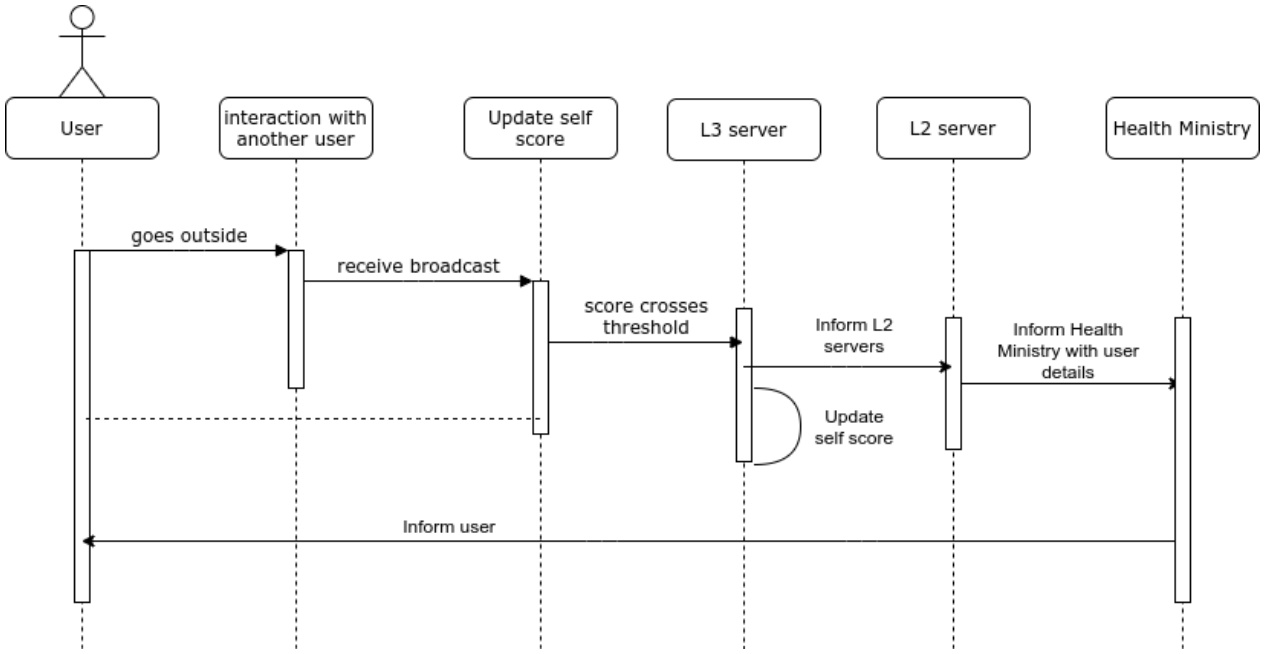

Figure 5: Sequence diagram for a user interacting with another

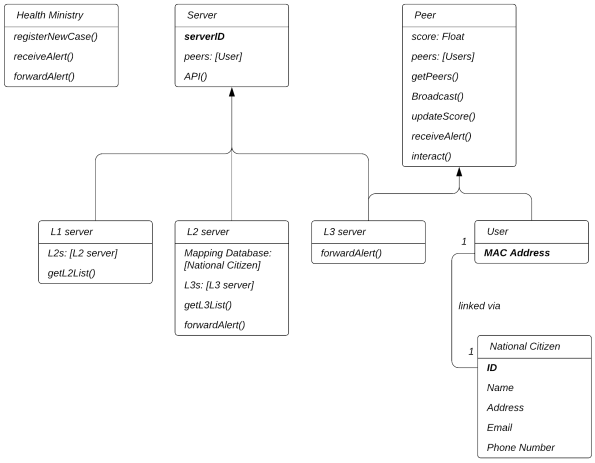

Figure 7: Class diagram

3.7. Possible problems and their solutions

- Users on different height levels separated by floors or by walls (people in a multi-level building on 4th and 6th floors for example).

  Solution: the signal strength will be very less since it has to cross walls and floors so this might not be an actual problem. We can also include altitude readings from the barometer[12]. To remove any doubts about this problem.

- It will be updating data even when people are at home.

  Solution: Over time, this problem will fix itself. If even one person goes outside for bringing groceries, the score changes. Since they are coming back to home, the scores of their family should also update. This is a feature and not a bug!

- People would go outside without their mobile phones.

  Solution: They will not. This solution helps them by identifying which areas are safe and if or not they are in the proximity of someone with high risk. They would go out with the application so that they remain safe.

- People have multiple mobile phones and might use any one of them while going outside.

  Solution: People will have to register in the application before they can use it. This ensures that they log in to all the devices they have which they will take outside with them. The scores will have to be synced across all the devices (via the L2 servers).

4. Conclusion

This solution is fast (bluetooth broadcasts take almost no time at all) and efficient (bluetooth low energy, BLE was made to run on IoT devices and hence are very energy efficient [15]), addresses any and all privacy concerns (no data being stored anywhere except being encrypted at the L2 servers) and will turn life slowly back to normal. This solution requires nothing but installing an app from the user's side. Everything else is managed by the servers.

Future work We need to deploy the servers in place. This will soon become a global initiative and we need to manage countries which might not have the infrastructure required to setup the L2 and L3 servers.

We also need to try out other scoring mechanisms, the dynamics of how they evolve, etc.

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